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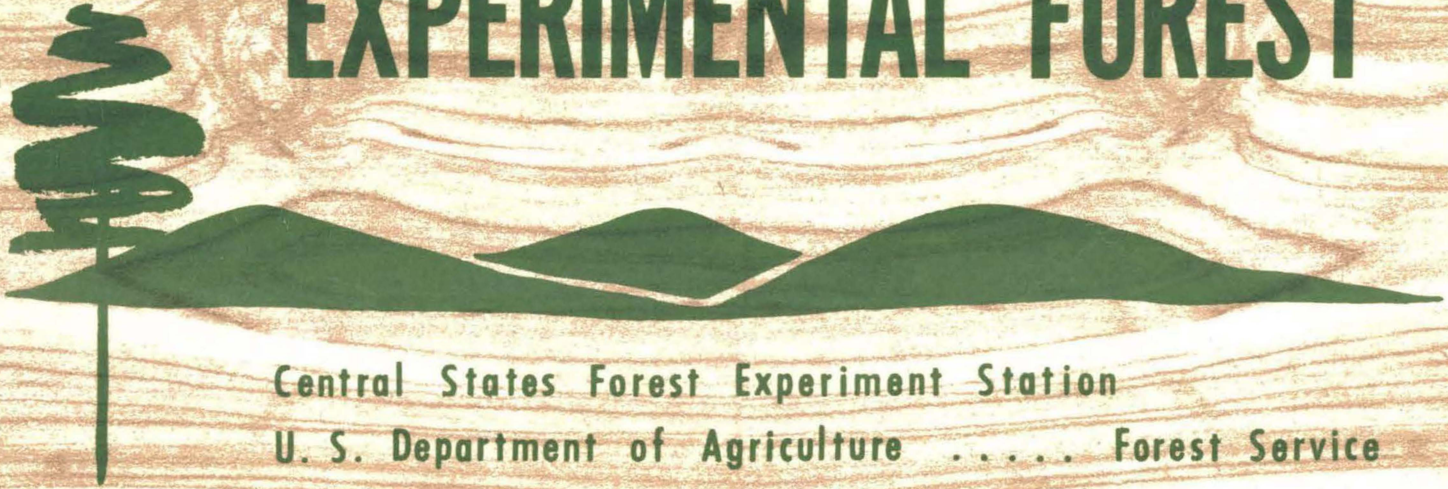


Central States Forest Experiment Station

U. S. Department of Agriculture ..... Forest Service

CONTENTS

page

Pine Conversion vs. Hardwood Management on Dry Ridge Sites . . 3

Forest Soil-Site Research 7

Cutting-Practice Demonstration 20

Release of Yellow-Poplar and Oak Seedlings 29

Intensive Cleaning in Sapling Stands 33

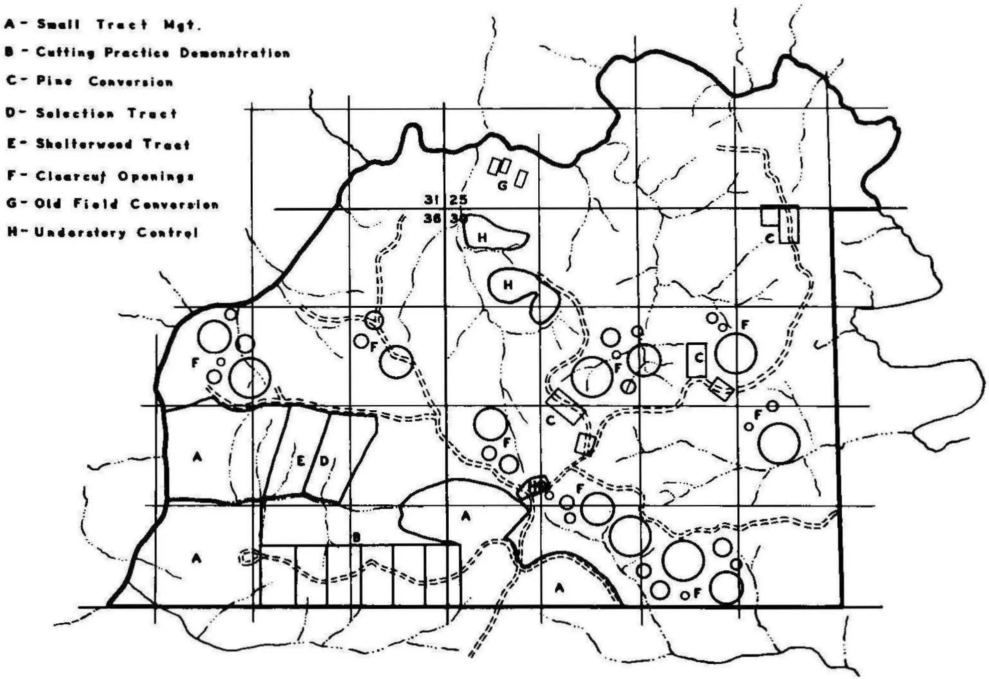
Small-Tract Management 34

Size-of-Opening Study 38

Tract-Size Studies of Tree Selection and Shelterwood Silvicultural Systems 42

VINTON FURNACE
EXPERIMENTAL FOREST

THE MEAD CORP. in cooperation with
U. S. FOREST SERVICE



A - Small Tract Mgt.
B - Cutting Practice Demonstration
C - Pine Conversion
D - Selection Tract
E - Shelterwood Tract
F - Clearcut Openings
G - Old Field Conversion
H - Understory Control

G
31 25
36 30
H
H
C
F
F
F
F
C
C
F
F
A
E
D
A
A
B
A
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One hundred years ago southeastern Ohio's thriving iron industry was stimulated to booming intensity by Civil War demands for iron and steel. Wood cutting for charcoal naturally increased correspondingly. Ore was smelted near the mines by more than 40 furnaces, all of which burned charcoal made from local wood. Five cords of wood yielded 200 bushels of charcoal and in 1860 one furnace alone burned 300,000 bushels. So the nearby forests were cut clean to meet this tremendous need for wood.

For more than half a century some of the best iron in the world flowed from these smelters. But the discovery of richer, more abundant ores in Michigan and Minnesota brought Ohio's iron industry to an end. Soon all that was left were the ruins of the furnaces--and thousands of acres of clearcut forest land.

The Experimental Forest was established in 1952 near the old Vinton Furnace. All the timber on the 1200-acre tract was originally cleared for charcoal, and the forest that developed after cutting is now 90 to 100 years old. While the stands contain many defective and cull trees, mainly because of frequent fires in the past, the trees have in general grown well and developed into good, well-stocked sawtimber stands of mixed black, white, chestnut, and scarlet oaks with occasional red oaks and yellow-poplars in the coves.

This 1200-acre tract was formerly owned by D. B. Frampton and Company which set the area aside as a field laboratory for forest research. It now belongs to the Mead Corporation which has also provided another experimental forest in Scioto County. Research on these forests is conducted by the Central States Forest Experiment Station from its Athens (Ohio) field office which was established in 1948 in cooperation with Ohio University.

This booklet describes some of the research work that we have begun on the Vinton Furnace tract during the past 10 years and more recently on the adjoining Raccoon State Forest.

PINE CONVERSION VS. HARDWOOD MANAGEMENT ON DRY RIDGE SITES

We began this study in 1954 to find out whether poor ridgetop hardwood stands could be converted to pine thus increasing timber production. For the first 5 years the planted pines survived and grew satisfactorily; many pines even grew faster than the hardwood sprouts. The prospects for successful conversion looked good indeed. Now, after the eighth growing season, this picture has changed somewhat: the pines that we released are still surviving and growing satisfactorily, but only the white pine has survived well without the benefit of release. Also, fewer of the unreleased pines are taller than the hardwood sprouts now. Thus release seems necessary to insure a successful conversion, especially for the less tolerant species.

This study comprises nine plots. On six of these we completely clearcut the hardwoods and planted a mixture of shortleaf, pitch, and white pine, (850 trees per acre); the other three plots are being managed for hardwoods. On the six planted plots, a heavy cover of hardwood sprouts sprang up almost immediately. To see if growth and survival would be increased, we released all the pines on half of these plots by cutting and poisoning the hardwood sprouts from around each of the planted trees. We released the pines during the first growing season (1954) and again in the third growing season (1956).

After 8 years survival is still adequate for all three species in the released plots, but only for white pine in the unreleased plots (table 1).

There are now 668 pines per acre (78 percent) remaining in the released plots, compared with 471 (56 percent) in the unreleased plots. White pine survived best, whether released or not. We found the best survival on the poorest site and poorest survival on the best site, probably because hardwood competition is much heavier on the better sites.

The pines are taller on the released plots than on the unreleased plots, and on the average shortleaf pine is tallest followed by pitch pine and then white pine. However, average heights are somewhat misleading. While the shortleaf and pitch pines average quite a bit taller than the white pine, this is

Table 1.--Survival and height of released and nonreleased pine after eight growing seasons

Species	Survival		Height	
	Released	Nonreleased	Released	Nonreleased
	percent	percent	feet	feet
White pine	88	71	9.5	6.5
Shortleaf pine	72	46	14.0	11.2
Pitch pine	74	49	12.3	10.2

partly because of their lower survival. Many of the less vigorous (and shorter) shortleaf and pitch have died leaving only the taller trees to be measured. But many of the shorter white pine are still living and thus lower the average. The last 3 years, white pine has grown faster than either shortleaf or pitch.

In 1958 we were encouraged when we found (on the unreleased plots) that the number of pines taller than the competing brush had increased since the previous inventory. This suggested that the pines were actually outgrowing the brush. Three years later, however, this trend had apparently reversed; there were fewer pines "free to grow" than there were in 1956 (table 2).

Table 2.--Pines that are taller than the sprouts surrounding them on the nonreleased plots

Species	Trees per acre			Av. heights		
	1956	1958	1961	1956	1958	1961
White pine	60	106	57	2.3	4.5	10.2
Shortleaf and pitch pine	178	251	159	4.0	7.1	12.1
Total	238	357	216	---	---	---

Release has significantly increased growth and survival of these plantations but in previous years this has not seemed too important because survival was always adequate and the difference in height actually not too great. Now, however, competition in the unreleased plots has reduced the pine stocking too far, and some release appears necessary to insure a successful conversion. Fortunately such a treatment also increases pine height growth. It is apparent, too, that the better the site, the more vigorously the sprouts grow. Hence the better the site, the more need there is for release.

FOREST SOIL-SITE RESEARCH

Our soil-site research will provide information on the growth and yield of important forest trees on different soils and topographic locations in southeastern Ohio. Foresters can use this knowledge to select the most productive tree species to establish and favor on specific sites.

About 150 one-fifth-acre plots have been established in even-aged, well-stocked, undisturbed oak stands distributed over 14 counties. We selected these plots to cover the wide range of soil, topography, stand age, and site quality found for upland oaks in southeastern Ohio. The data from these plots have been analyzed to determine the combination of soil and topographic features that will best depict black oak site quality. From this analysis we have developed regression equations that explain about 80 percent of the differences in tree height growth measured on the site plots. For the two major upland soil groups in southeastern Ohio, this is what we found:

a. Well-drained, medium-textured soils (Muskingum, Wellston, and Gilpin soil series)

   (1) Site quality increases with increased thickness of surface soil ($A_1 + A_2$ horizons).
   (2) Best site quality is on north and east slopes while poorer sites occur on south and west slopes.
   (3) Best sites are found on lower slopes and in coves while the poorer sites are on upper slopes and ridges.

(4) Site quality decreases as the stone content of the subsoil (B_1 horizon) increases.

b. Fine-textured soils with restricted internal drainage (Rarden, Coolville, Keene, Lathem, and Upshur soil series)

(1) Site quality increases with increased thickness of surface soil ($A_1 + A_2$ horizons).
(2) Site quality increases with increased steepness of slope.
(3) Poorest sites have heavy-textured clay subsoils (B_1 horizons); better sites have somewhat lighter textured subsoils.

Regression equations containing the features listed above were used to calculate black oak site index1/ for the two major soil groups (tables 3 and 4). These tables can be used to estimate black oak site index in all upland forests throughout southeastern Ohio.

1/ An index of site productivity based on the height of the dominant trees at 50 years of age.

Table 3.--Site index for black oak on well-drained, medium-textured soils (Muskingum, Wellston, Zanesville, and Gilpin soil series)[1]

Slope position	Aspect[2]	Depth of surface soil[3] (inches)				
		Less than 2.0	2.1-3.0	3.1-5.0	5.1-8.0	More than 8.1
Ridges and upper quarter of SE to NW slopes		55	59	63	67	70
Upper half of slopes other than upper quarter of SE to NW slopes	SE to NW	58	62	66	70	73
	E to SE	61	65	69	73	77
	N to E	64	68	72	76	80
Lower half of slopes other than lower quarter of N to E slopes	SE to NW	63	67	71	75	79
	E to SE	66	70	75	79	83
	NW to N	69	73	78	83	87
Bottoms and lower quarter of N to E slopes		73	77	82	87	91

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[1] Site-index values are for soils that have relatively small amounts of stone (less than 30 percent stone in upper portion of subsoil (B_1 horizon)). For stony soils (more than 30 percent stone in B_1 horizon) subtract the following from the listed site-index values: (a) subtract 3 feet from values smaller than 60 feet; (b) subtract 4 feet from values 60 to 70 feet; (c) subtract 5 feet from values greater than 70 feet.

[2] SE to NW aspect represents 126° - 324° azimuth; E to SE aspect represents 91° to 125° azimuth; NW to N aspect represents 325° to 359° azimuth; N to E aspect represents 0° to 90° azimuth.

[3] Total thickness of $A_1 + A_2$ soil horizons.

Table 4.--Site index for black oak on soils with restricted internal drainage (Rarden, Coolville, Keene, Lathem, and Upshur soil series)

Texture of upper subsoil (B_1 horizon)	Slope (percent)	Depth of surface soil[1] (inches)			
		Less than 2.5	2.6-4.5	4.6-6.5	More than 6.6
Heavy clay (20-30 percent silt)	0 - 5[2]	47	52	57	63
	5 - 15	50	54	60	66
	15 - 25	52	57	63	69
	25 - 35	55	60	66	73
Light clay (30-40 percent silt)	0 - 5[2]	51	56	62	68
	5 - 15	53	59	65	71
	15 - 25	56	62	68	75
	25 - 35	59	65	71	78
Silty clay, silty clay loam, clay loam (more than 40 percent silt)	0 - 5[2]	54	59	65	72
	5 - 15	56	62	69	75
	15 - 25	59	65	72	79
	25 - 35	63	69	76	83

[1] Total thickness of $A_1 + A_2$ soil horizons.

[2] Usually relatively flat ridges.

SOIL TYPES

Site quality is extremely variable within each of the soil types recognized by the Ohio Soil Survey (fig. 1). In fact, the variation in site index is so great that soil types alone cannot be used to estimate site accurately for any specific local area. This is because soil types in the unglaciated hill country are not detailed enough to precisely reflect all the factors that influence forest site. Thus they will need to be refined to include the specific features of soil and topography that are related to tree growth before soil types can be used for accurate site prediction.

UNDERSTORY VEGETATION

Preliminary analysis shows several understory herbs and shrubs that indicate differences in black oak site quality.

a. Good Sites

Black snakeroot	(*Cimicifuga*)

Wild hydrangea	(*Hydrangea*)
Beggarticks or tick-trefoil	(*Desmodium*)
Bittersweet	(*Celastrus*)
Rattlesnake fern	(*Botrychium*)
False Solomon's seal	(*Smilicina*)
Trillium	(*Trillium*)
Broadleaf sedge	(*Carex*)
Wild geranium	(*Geranium*)

b. Poor Sites

Dittany	(*Cunila*)
Povertygrass	(*Danthonia*)
Pussytoes	(*Antennaria*)
Dryland blueberry	(*Vaccinium vacillans*)
Cinquefoil	(*Potentilla*)
Hawkweek	(*Hieracium*)
Rose	(*Rosa*)
New Jersey tea	(*Ceanothus*)

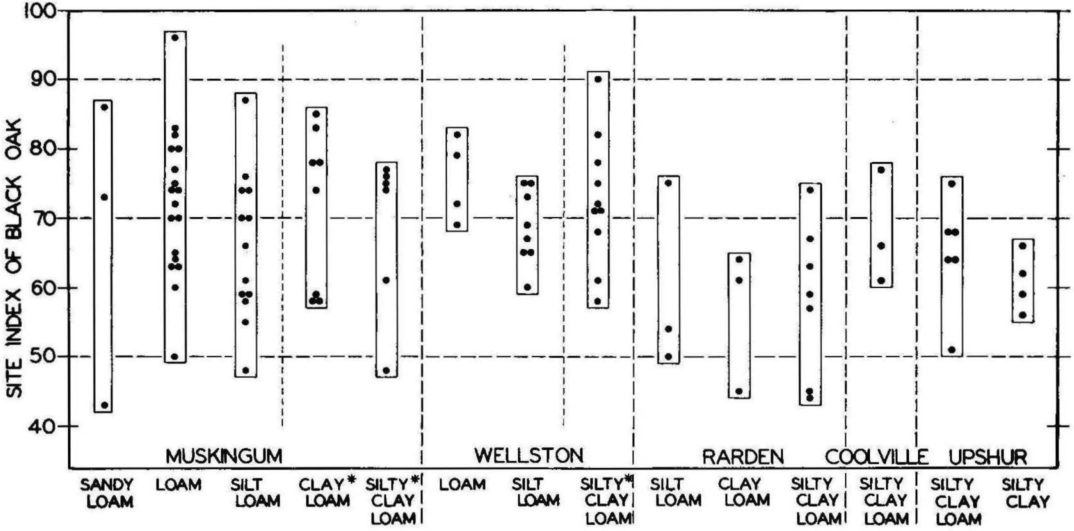

Figure 1.--Site index of black oak varies widely within upland soil types commonly found in southeastern Ohio.

Eventually we may be able to describe several broad site classes based on the occurrence and distribution of these site-indicator plants. The method is not much help when plants are dormant, and it can be used only in well-stocked stands that have not been recently disturbed. Thus the method does not have as broad an application as site estimation based on soil and topography. However, indicator plants will be very helpful as a supplement to other methods; for example, as an aid in mapping site quality by making it easier to locate boundaries between soil and site quality classes.

SITE-INDEX CURVES

Using the data from the soil-site study, we have calculated preliminary curves of black oak height growth. For a given site index, these curves show the height that dominant black oaks will attain at any age. When our curves are compared with the standard site curves for upland oaks[2], it appears that height growth of black oak in southeastern Ohio declines more rapidly after 50 years than is predicted by the Schnur curves (fig. 2). Moreover, height growth for black oak differs on the two major upland soil groups in southeastern Ohio. After 50 years, height growth of trees on fine-textured soils with restricted internal drainage slows up much more than it does for trees on the well-drained, medium-textured soils. Finally, Olson's site-index curve for oak in the southeast compares very favorably with the curve for the well-drained, medium-textured soil group.

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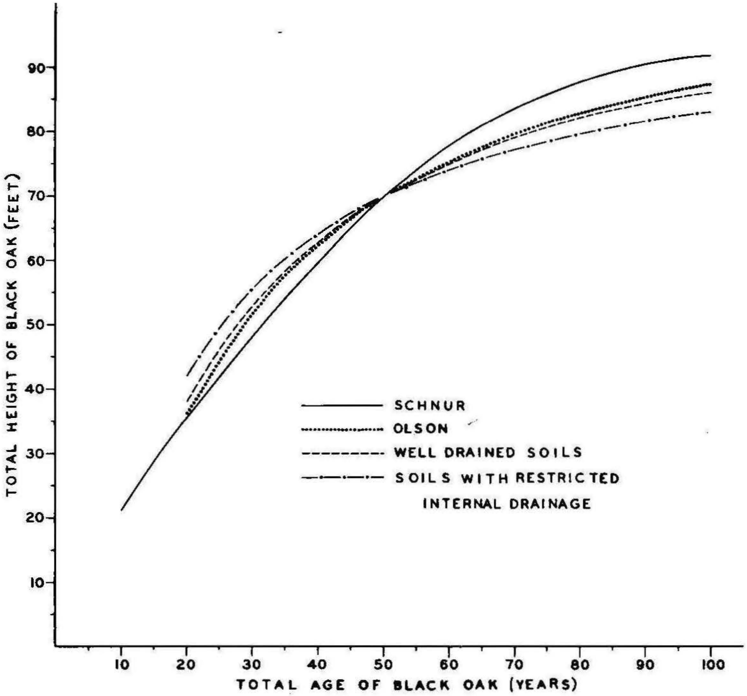
[2] Schnur, G. Luther. Yield, stand, and volume tables for even-aged upland oak forests. U.S. Dept. Agr. Tech. Bul. 560, 88 pp., illus. 1937.

These results show that using the standard curves will often lead to incorrect estimates of site index in southeastern Ohio. Errors will be particularly pronounced for old (more than 65 years) or young (less than 35 years) stands.

SITE-INDEX COMPARISONS

Site measurements were made for all species of oak growing on each site plot. Thus site index measured for one species can be compared with the site index of other oak species. Site index of scarlet oak exceeds that of black oak which, in turn, is higher

Figure 2.--Height growth of black oak in southeastern Ohio declines more rapidly after 50 years than is predicted by Schnur's site-index curves. This decline is greater for trees growing on fine-textured soils with restricted internal drainage. But growth on medium-textured, well-drained soils is similar to that predicted by Olson's site curves for oak in the Southeast.



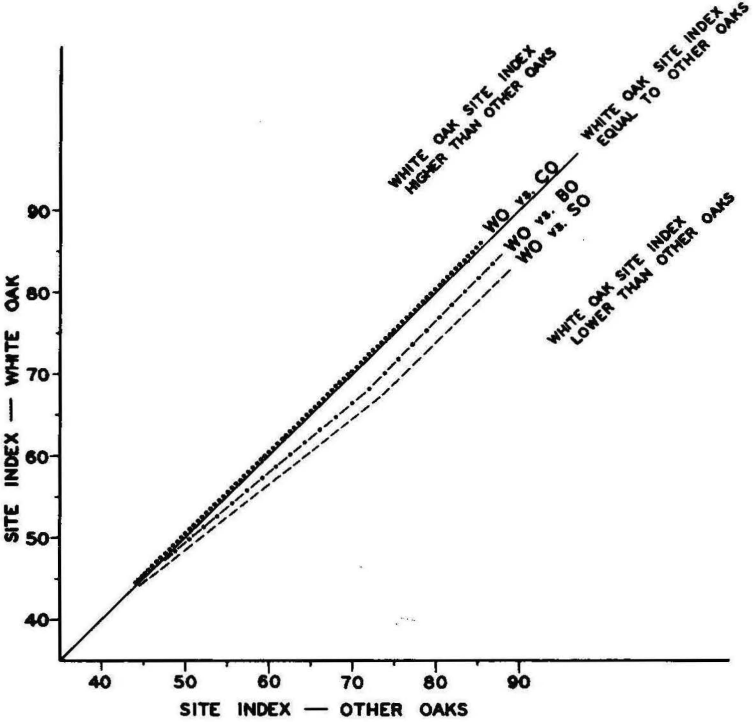


Figure 3.--When several species of oak are growing together the site index of scarlet oak exceeds that of black oak which, in turn, is higher than the site index of white and chestnut oak. These differences are more pronounced on good sites than on poor sites.

than the site index of both white and chestnut oak (fig. 3). The differences are greater on good sites than on poor sites. We conclude that site-index estimates should be based on separate measurements of each species of oak rather than on average of measurements combined from several species. When these data are completely analyzed we will be able to use site index of one species of oak as a basis for predicting site index of other species on the same area.

CUTTING PRACTICE DEMONSTRATION

This is a demonstration of six different harvest-cutting methods that we have tried in central hardwood forests. We want to compare the growth and reproduction that result. Each plot contains 5 acres plus an isolation strip that brings the area in each treatment to 8.4 acres. The first four plots were cut initially in 1953-54; Plots 5 and 6 were cut 2 years later

TREATMENTS

Plot 1 we call a "Commercial clearcut." We cut every tree that was large enough to make an 8-foot sawlog 10 inches in diameter. We removed two-thirds of the basal area and all the sawtimber volume. The residual stand is poorly stocked and contains poles, mostly of low quality, and cull trees.

Plot 2 is a "Diameter limit" cut. Every merchantable tree that exceeded these diameters was cut: yellow-poplar--20 inches; white oak--18 inches; black, red, and chestnut oaks--16 inches; scarlet oak--14 inches; and hickory--12 inches. We selected these cutting diameters to leave larger trees of the more valuable species for further growth and seed production. No stand improvement work was done and the residual stand contains many culls. We removed about 30 percent of the basal area, and one-fourth of the sawtimber volume in the first cut and made a second cut in this plot in the winter of 1961.

Plot 3 was a "Selection" cut. We took out only merchantable trees that were mature, damaged, or defective. We removed one-third of the basal area and about 20 percent of the merchantable volume, but, as in the first two plots, many culls and undesirable trees remain. A second cut was made in this plot in the winter of 1961.

Plot 4 was a "Complete clearcut." All trees merchantable for sawlogs and pulpwood were removed. In addition, everything else over 4 1/2 feet tall was cut and left on the ground. We thus removed all of the basal area and volume. Obviously, it will be a long time before the plot yields another harvest cut, but the quality of the reproduction is excellent, and none of the growing space is being wasted by residual cull trees.

Plot 5 was cut "Selectively," like Plot 3, but here we did some improvement work in the stand that was left. Defective trees and undesirable species have been killed; desirable young growth will be released if it becomes necessary. We removed one-half of the basal area, and about 40 percent of the sawtimber volume.

Plot 6 is a second "Commercial clearcut," like Plot 1, but culls and undesirable species were removed too. The stand that remains is grossly understocked and will not produce good-quality wood because of the great amount of epicormic branching.

STAND DATA

	Original stands		Residual stands	
	Volume (bd. ft.)	Basal area (sq. ft.)	Volume (bd. ft.)	Basal area (sq. ft.)
Commercial clearcut	5,000	86	225	32
Diameter limit	6,170	101	4,700	70
Selection (no TSI)	5,590	78	4,500	53
Complete clearcut	8,000	91	0	0
Selection (with TSI)	8,100	88	4,940	44
Commercial clearcut (with TSI)	7,540	96	0	4

GROWTH

Five-year-growth rates have been calculated for four plots. The most growth occurred on Plot 5.

	Plot 1 Commercial clearcut (bd. ft.)	Plot 2 Diameter limit (bd. ft.)	Plot 3 Selection (no TSI) (bd. ft.)	Plot 5 Selection (with TSI) (bd. ft.)
Growth on residual trees	50	192	200	234
Ingrowth	104	64	29	31
Less mortality	-1	-46	-47	-9
Net growth	153	210	182	256

However, in uncut stands that were similar to these initially, net growth has ranged from 180 to 230 board feet per acre per year.

None of the cutting methods, therefore, has increased growth very much in these 90-year-old stands.

Part of the increase in Plot 5 is due to faster growth of the residual stand; part of it is due to lower mortality. Unfortunately, we don't know whether the increase is due to treatment, or perhaps to better site conditions and larger trees on Plot 5 initially. We suspect the latter. We can infer, however, that a fairly heavy cut (40 percent or more of the volume) is required in these mature, well-stocked stands to reduce mortality. But even if such heavy cuts should reduce mortality and increase growth slightly, the increase is gained at the expense of quality. There are many epicormic branches on the boles of trees near the larger openings.

Of course, future measurements will be needed to check the accuracy of the growth figures. If these early trends are confirmed, the lesson will be clear: mature, mixed-oak stands do not respond to partial cuts. They need to be reproduced--not thinned.

REPRODUCTION

Two years after cutting, all plots contained ample reproduction, but the heavier the cut the more yellow-poplar there was; the lighter the cut, the more oaks. Five years later the reproduction was counted again in the same 3 plots, and Plot 5 was tallied for the first time. In an attempt to make an early prediction of what the final stand will be in each plot, only the stems more than 4.5 feet tall are included below:

Reproduction more than 4.5 feet tall 7 years after cutting[3]

	Plot 3 (1/3 B.A. cut)	Plot 5 (1/2 B.A. cut)	Plot 1 (2/3 B.A. cut)	Plot 4 (All B.A. cut)
Yellow-poplar	40	130	290	550
Oaks	590	510	810	590
Hickory	450	340	610	370
Red maple	210	90	330	920
Other trees	200	350	150	690
Total	1,490	1,420	2,190	3,120

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[3] Five years after cutting for Plot 5.

The amount of yellow-poplar (and other intolerant species) still closely follows the intensity of the cut; but the amount of oak over 4.5 feet tall is about the same in each plot. The numerous red maples in Plot 4 sprouted vigorously from the small stems that were chopped down in the understory of the original stand.

Numbers alone, however, don't tell the whole story. Obviously, the reproduction in the full sunlight in Plot 4 is growing much faster than that in the partial shade in the other plots. After 8 years the canopy in Plot 4 reaches from 20 to 25 feet high, and the stems that survive the intense competition are straight, clean, and vigorous. The main lesson here is that very heavy cuts are necessary to reproduce intolerant species. Clearcutting is recommended in mature stands.

In Plot 4 the final stand will probably contain a good percentage of yellow-poplar (much greater than the 5 percent of the original stand) despite competition from the red maple; three-fourths of the tall yellow-poplar stems are dominant or codominant. The plot contains many nice oaks and other intolerant species also. However, the yellow-poplar is much more frequent on the north slope of Plot 4 than on the south slope: about 800 tall stems per acre versus 300. Apparently, on the good, north-slope site, many yellow-poplar seedlings are growing fast enough to compete successfully with red maple sprouts. On the south slope, the seedlings could not compete with the maple sprouts and were crowded out; only sprouts from the yellow-poplar seedlings (that were chopped down in the original understory) can keep up with the maple sprouts on this drier site. The lesson to be learned here is: In making reproduction cuts don't chop down small stems of undesirable species unless you also poison them to prevent sprouting. On Plot 6 (where the understory stems were not cut) there are few sprouts and little red maple.

In the other plots, the stands will continue to be made up mostly of mixed oaks. Plots 1 and 5 will probably contain some yellow-poplar; Plot 3 will have little, if any, unless future cutting provides larger openings.

Although the reproduction in Plot 6 is good, the residual trees are becoming wolf trees, usurping more and more of the area. Even though they grow large, they will be of little value; the numerous branches mean knotty, low-quality timber. The moral is: Don't leave large saplings and poles scattered in an area after a reproduction cut.

RELEASE OF YELLOW-POPLAR AND OAK SEEDLINGS

A few years after making the complete clearcut in Plot 4 of the Cutting-Practice Demonstration, we counted more than 6,000 yellow-poplar seedlings and almost half that many oak stems per acre. This was encouraging, but the dense tangle of vines, shrubs, and undesirable trees (covering an estimated three-fourths of the area) threatened to crowd out many of the desirable stems.

It would be embarrassing indeed if we lost so much of this fine reproduction that we ended up with a final stand of "junk." So we set out to find (1) how effective release cuttings are for bringing yellow-poplar and oak seedlings through this dense woody and herbaceous plant cover, (2) to what extent release will increase the growth of previously overtopped reproduction, and (3) whether desirable trees that were dominant at 5 years of age would continue to outgrow competition.

One hundred pairs of overtopped oak or yellow-poplar seedlings were selected, tagged, and measured in the summer of 1958. One seedling of each pair was released by clearing a circle of about 1 foot in radius around the stem; the other seedling was left to struggle along on its own. A second release was necessary the next summer. In addition a number of single seedlings that did not appear to need release were also tagged for future measurement.

The seedlings selected as free to grow have consistently grown faster than the other tagged seedlings (table 5). In 1961 we found also that two-thirds of the yellow-poplar selected as free to grow were still free but only one-fourth of the oaks were still outgrowing the brush. In numerical terms, 7 years after cutting we found 420 yellow-poplar per acre in this category, enough to encourage us to think that the future stand will have a good species composition.

Table 5.--Height growth of seedlings in 1961, four growing seasons after release

Species	Treatment[1]	Trees free to grow	Average height growth
		percent	feet
Yellow-poplar	F	68	2.9
	R	45	1.8
	NR	10	.9
Oaks	F	26	1.3
	R	24	.9
	NR	3	.3

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[1] F, free to grow in 1958; R, release needed and released; NR, release needed but not released.

Each year the released seedlings appeared to have grown more than the unreleased, but 1960 was the first year that the difference in seasonal growth was statistically significant. By 1961 the released yellow-poplar were growing twice as fast as those not released, and the released oaks were growing three times as much as those not released.

In spite of the increased growth resulting from the release, only about half of the released yellow-poplar and a fourth of the released oaks are still free to grow. Moreover, almost none of the unreleased seedlings are free to grow. Thus we cannot expect many seedlings that are not dominant by 5 years of age to become so, and we cannot plan on all released trees to remain free.

Although the released trees grew more than those not released, they did not grow as much as those that had been free to grow to begin with. Also, more of the free-to-grow trees than the released trees have maintained dominance. We conclude therefore, that some desirable trees will come through the dense growth that develops after clearcutting without release. However, to improve composition or distribution in the final stand a release cutting may be necessary, and it may take more than one.

INTENSIVE CLEANING IN SAPLING STANDS

Eight years after making the complete clearcut (Plot 4 of the Cutting-Practice Demonstration), there are more than enough good yellow-poplar saplings in the plot to provide crop trees for the future. But there are also lots of vigorous red maple sprouts. So--do the yellow-poplars need help, or don't they? Even if they don't actually need help, will they grow faster if they don't have to fight the competition? And finally, even if crop-tree growth is not increased, how much will a heavy cleaning improve the composition and spacing of the final stand? A small study was established in 1961 in an attempt to answer these questions.

Two plots were laid off into squares 15 links on a side. In each square the most promising yellow-poplar (occasionally an oak) was selected as a crop tree. This spacing amounts to 444 trees per acre, enough to provide full stocking by the time the trees are 4 to 6 inches in diameter.

In both plots the crop trees were carefully measured and their locations spotted on a map with reference to nearby taller trees (if any) which were also measured. On the check plot, nothing further was done. On the treated plot, however, all vegetation was cut and poisoned, except the crop trees, of course, Successive tallies and measurements will show differences in composition and growth caused by the cleaning.

Initially 40 percent of the squares were dominated by red maple sprouts, 31 percent by yellow-poplar, 15 percent by aspen, 10 percent by chestnut oak sprouts, 2 percent by scarlet oak, 2 percent by hickory.

SMALL-TRACT MANAGEMENT

Our small-tract management study is designed to study a method of making periodic harvests in small woodlands. Because the timber on the Experimental Forest is essentially even-aged, the study must include a system of converting the stands to an orderly succession of age classes, and at the same time provide for systematic timber harvests and the reproduction of desirable species.

In this study there are three tracts, each about 50 acres in size. They are all being managed on a nominal 80-year rotation, but each tract has a different cutting interval: 1 year, 5 years, or 10 years.

To get the kind of reproduction we want, we are clearcutting in patches, so we must arrange to clearcut an equal area each interval to end up with an even distribution of age classes. For the 1-year-cutting-cycle tract, 1/80 of the area will be clearcut each year. We expect that by the end of 80 years, there will be 80 little stands of trees, the oldest stand being 80 years old and the youngest only 1 year old. On the other hand, for the 10-year-cutting interval, 1/8 of the area will be cut every tenth year and we will end up with 8 age classes with a 10-year difference between classes. This same principle will be applied to the 5-year cycle: 1/16 of the area will be cut each year to provide 16 age classes.

However, these stands are already 100 years old. If we restricted the cut to only the volume that came off the clearcut patches each cutting interval, by the end of the rotation many old trees would have died. Therefore, in all tracts the first cut was fairly heavy in order to allow the needed stand improvement work to be done as early as possible. In the subsequent cuts 1/80 of the volume remaining after the first cut will be removed for each year that elapsed during the interval plus an amount equal to what the stand has grown during that time.

Using this system the amount cut each time should gradually decline because more and more of the tract will have been clearcut, and a continually decreasing portion of the original stand will provide merchantable volume growth. However, as trees again develop on the clearcut areas and reach merchantable size, volume removed by intermediate cuttings in the new stands will add to the harvest.

Whenever the area to be clearcut does not yield the total required to be cut, the remainder of the volume needed to make up the cut is taken from the rest of the tract on a stand improvement basis.

To date only the first cut has been made in the 10-year-cutting-cycle tract; while the 5-year-cutting-cycle tract has had two cuts and the 1-year tract has been cut six times.

Here are some comparative figures for the three tracts:

	Tract I	Tract II	Tract III
Area	52 acres	47 acres	46 acres
Cutting cycle	10 years	5 years	1 year
Original volume	281 MBF	252 MBF	256 MBF
Area cut each cycle (Approx.)	6 acres	3 acres	1/2 acre
Volume of 1st cut	80 MBF	52 MBF	44 MBF
Volume of 2nd cut	90 MBF (est.)	48 MBF	8 MBF
Volume of 3rd cut			8 MBF
Next cut due	1965	1965	Annually

SIZE-OF-OPENING STUDY

The numerous saplings in each of the cutting-practice plots make it clear that the quantity of reproduction will be adequate, no matter what cutting system is used. However, the quality of the reproduction--the species composition and rate of growth--may vary widely from one system to another. Cutting methods that create openings favor the establishment and rapid growth of intolerant species. So a study was begun to compare species composition and growth rate of reproduction in clearcut openings of various sizes and on various sites.

Thirty-six plots have been installed: 18 on good sites (site index for black oak 70 to 85), 18 on poorer sites (site index 50 to 65). Within each site class there are 3 circular plots of each of the following sizes: 1/8, 1/4, 1/2, 1, 3, and 5 acres. We harvested all merchantable timber on the plots, and poisoned all non-merchantable trees larger than 2 inches d.b.h. On permanent sample milacres (about 800 altogether) we counted the advance reproduction immediately after logging, and have since made two more counts.

All species have increased in both numbers and distribution since cutting except the red and black oaks on the good site, and possibly the white oak on the poorer site. On both sites yellow-poplar has increased the most (tables 6 and 7).

Site quality seems to make a lot of difference in the number of stems of oaks, yellow-poplar, red maple, blackgum, sassafrass, sourwood, and "other brush" (mostly witch-hazel and alder). It probably also affects the numbers of ash, cherry, aspen, elm, and other trees, but these species are too scarce for reliable comparisons.

So far, size of opening doesn't seem to make much difference in the number of stems per acre, except that yellow-poplar seedlings are not quite as numerous in the smaller openings. However, growth rates may be slower in the smaller openings because more of the area is shaded by the surrounding stand. Future measurements will tell.

Nevertheless, it is plain that adequate desirable reproduction follows clearcutting on areas as large as 5 acres, and

Table 6.--Reproduction on clearcut plots immediately after logging and 2 years after cutting--good sites

	Number of stems per acre		Frequency[1]	
	Advance	2 yrs after cutting	Advance	2 yrs after cutting
Red & black oaks	1,720	1,490	51	56
White oak	350	570	17	24
Chestnut oak	170	700	10	15
Yellow-poplar	250	18,620	12	91
Hickory	480	1,000	35	37
Maples	1,230	1,880	48	47
Blackgum	250	980	16	30
Ash, cherry, others	350	780	14	26
All trees	4,800	26,020		
Dogwood	3,030	4,750	54	60
Sassafras	1,250	2,930	49	58
Sourwood	260	580	12	10
Other brush	2,550	3,200	58	45
All brush	7,090	11,460		

[1] Percent of milacres on which species were found.

Table 7.--Reproduction on clearcut plots immediately after logging and 2 years after cutting--poor sites

	Number of stems per acre		Frequency[1]	
	Advance	2 yrs after cutting	Advance	2 yrs after cutting
Red & black oaks	2,460	3,550	75	83
White oak	240	250	13	13
Chestnut oak	890	1,190	33	34
Yellow-poplar	390	4,150	15	63
Hickory	870	1,040	54	56
Red maple	590	820	22	23
Blackgum	950	1,520	40	37
Other trees	80	280	4	15
All trees	6,470	12,800		
Dogwood	2,120	4,100	33	35
Sassafrass	2,490	5,190	73	85
Sourwood	660	1,580	29	38
Other brush	560	960	19	21
All brush	5,830	11,830		

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[1] Percent of milacres on which species were found.

at least as small as 1/2 acre. Within these limits the size of opening to make should depend on topography (site conditions should be roughly similar throughout), and the size of area that will best fit future management.

TRACT-SIZE STUDIES OF TREE SELECTION AND SHELTERWOOD SILVICULTURAL SYSTEMS

We are attempting a side-by-side evaluation of the tree selection and shelterwood systems as described in textbooks. The selection system is a method of uneven-aged management in which frequent, relatively light cuts are made to produce and maintain an all-aged stand. The shelterwood system, on the other hand, is a method of even-aged management in which the stand is harvested in two to four heavy partial cuts to establish reproduction of uniform age under the partial shelter of seed trees. We are chiefly interested in comparing the reproduction produced under these two systems.

In these even-aged, mixed oak stands, we cannot adhere exactly to the textbook description of selection because that presupposes an all-aged stand. Selection cutting, however, has been widely prescribed for stands similar to this. Therefore, to provide for the conversion of this stand to an all-aged condition, we have had to compromise on the system's basic principle of harvesting only the oldest or largest trees. Thus, our first cuttings have concentrated on removing (1) the trees that are dead, dying, damaged, or defective and (2) large residual trees when their removal will benefit an established stand of a smaller size class. But, we are trying to follow closely the other principles of single-tree selection cutting: cut conservatively and avoid creating large openings in the canopy, remove at each cut only a volume equal to the periodic growth, and do any stand improvement work that will benefit the remaining trees.

In the selection tract the cut has been set at 500 board feet per acre and subsequent cuts are made whenever the stand has grown that amount. To date we have cut this tract twice. The first cut, made during winter 1956-57 removed 675 board feet per acre and the second cut, made in 1959-60, removed 531 board feet per acre. The next cut is scheduled for 1962-63.

In the shelterwood tract our first cut was a combination preparatory and seed cut. A preparatory cut removes only intermediate and suppressed trees from the understory to develop conditions on the ground favorable for natural seeding. A seed cut removes some of the trees in the overstory to let in light and aid in establishing new seedlings. In this timber type we saw no need for separate preparatory and seed cuts, and our first cut removed two-thirds of the basal area and one-half of the sawtimber volume.

Here are the volume and basal-area statistics for the first cut on the two tracts:

	Shelterwood tract	Selection tract
Net volume per acre before cutting	6,471	7,074
Net volume per acre removed	3,317	[5] 675
Percent volume removed	51	9.5
Basal area per acre before cutting (4" d.b.h.+)	89.7	88.1
Basal area per acre removed	59.0	7.5
Percent basal area removed	66.0	8.5

We haven't decided yet how many removal cuts will be made in the shelterwood or when, because that will depend on how reproduction develops. Before treatment we made counts in each tract, so we have a good idea of the advance reproduction before cutting:

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[5] A heavier cut than planned because of the need to salvage trees damaged by a severe windstorm.

Species	Selection tract		Shelterwood tract	
	Stems per acre	Frequency[6]	Stems per acre	Frequency[6]
Oak	6,140	60	6,280	61
Yellow-poplar	430	8	40	1
Other trees	1,660	25	2,340	32
Total trees	8,230	71	8,660	76
Brush	14,400		15,600	
Total stems	22,630		24,260	

But we must wait for several more counts before we make the final cut in the shelterwood tract because we don't know how much reproduction was destroyed during logging, or whether what was left will live and grow.

6/ Percent of milacres on which species were found.